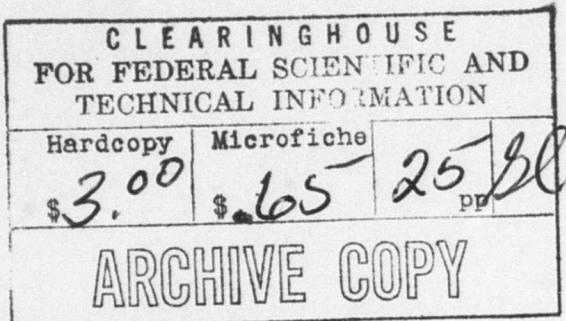


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ROCKET PAYLOADS

PROJECT MANAGER: J. R. CAMPOS

This work was sponsored by the Defense Atomic Support Agency under Project No. 5710



Bedford, Massachusetts

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GCA CORPORATION
BEDFORD, MASSACHUSETTS

FINAL REPORT

PERIOD COVERED: 1 AUGUST 1965 THROUGH 31 JULY 1966

CONTRACT NO. AF19(628)-5555

PREPARED FOR
AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS 01730

AFCRL-66-690

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FOREWORD

The work covered by this report was performed under Contract No. AF19(628)-5555, from 1 August 1965 to 31 July 1966 by GCA Technology Division, GCA Corporation, Bedford, Mass., Contract Monitor Mr. Frank A. Marcos.

This technical report has been reviewed and is approved.

ABSTRACT

Payloads consisting of TMA and sodium were constructed and one was flown from the Eglin Test Range in Florida. Two 70-MM cameras suitable for twilight and night trail photography were designed and developed along with an adjustable camera mount for pointing in azimuth and elevation and a timing console for sequentive automatic exposures. Refinements of existing procedures for obtaining estimated wind velocity data led to the development of photographic projection technique, which can be programmed for use with a computer.

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SECTION I

INTRODUCTION

This is the final report for Contract No. AF19(628)-5555. The work accomplished by the Technology Division of the GCA Corporation during the period covered by this contract is discussed under the following categories in this report.

1. The development and fabrication of one sodium payload and two trimethylaluminum payloads, including the firing of one of each as a combined payload at Eglin Test Range, Florida. The remaining TMA payload is being held in storage by GCA.
2. The design, development, and fabrication of two 70-MM cameras suitable for twilight and night trail photography.
3. The design, development, and fabrication of an adjustable camera mount assuring stability and freedom of pointing in azimuth and elevation and a timing console which allows sequential automatic exposures to be made.
4. The development of a photographic projection technique to permit wind velocity data to be estimated from stereo photographs within one hour of the chemical release experiment.

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SECTION II

ROCKET PAYLOADS

The rocket payloads, one sodium and two trimethylaluminum (TMA), were developed and fabricated as required in the Statement of Work, Items 1 and 2. They were designed to be flown individually with a Nike-Apache rocket. The individual canisters and instrumentation racks are shown in Figures 1 and 2.

During a technical discussion held at ESD on 15 October 1965, it was suggested that one of the TMA payloads be combined with a sodium payload as a single payload suitable for firing with a Nike-Javelin rocket. This configuration (Figure 3) using a standard, 11-degree nose cone and aluminum shells on the two instrumentation racks would be approximately 88.6 inches long and would weigh about 105 lb (exclusive of the coupling ring between the TMA canister and the shell of the sodium instrumentation rack).

The strength and stability of the payload was increased with two new shells fabricated of stainless steel (no. 304) and the coupling ring of cold rolled steel (No. 1018). These modifications boosted the combined payload weight to approximately 127 lb. The adapter section from the 9-inch Javelin motor to the 6-5/8 inch sodium canister was supplied by ESD.

Since the TMA is released on the ascent portion of the trajectory and the sodium on the descent, the TMA rack was provided with 90 sec timers and the sodium rack with 300 sec timers. The diameter of the TMA orifice was selected at 0.050 inch and drilled at the launch facility. The sodium canister had three standard exit ports of one inch diameter.

Two control consoles and two umbilical cables were supplied for pre-launch monitoring of the combined payload (Item 3). Both umbilical connectors employed explosive disconnectors.

Field services were provided as requested (Item 4). For the combined payload, it was necessary to have two men to integrate the payload to the rocket vehicle and to provide pre-launch checkout and monitoring of the combined payload during the countdown.

The sodium payload developed under Item 1 and one of the TMA payloads developed under Item 2 were successfully flown as a combined payload from Eglin Test Range, Florida, on 18 November 1965. The configuration was a stable payload on the Nike-Javelin rocket and the sodium and TMA release occurred as planned, meeting all experiment objectives. The remaining TMA payload under Item 2 is being held in storage by GCA.

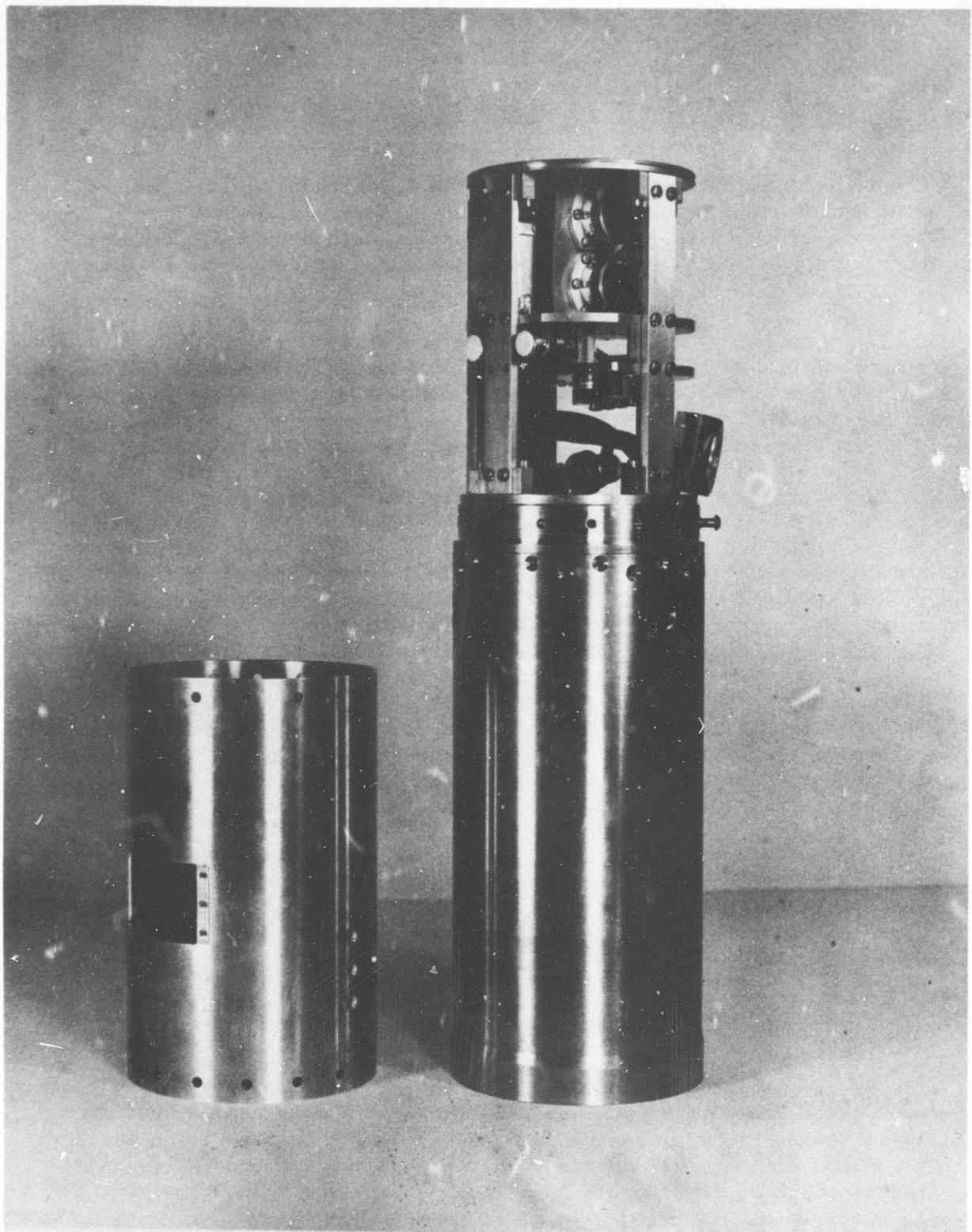


Figure 1. Sodium payload rack and canister.

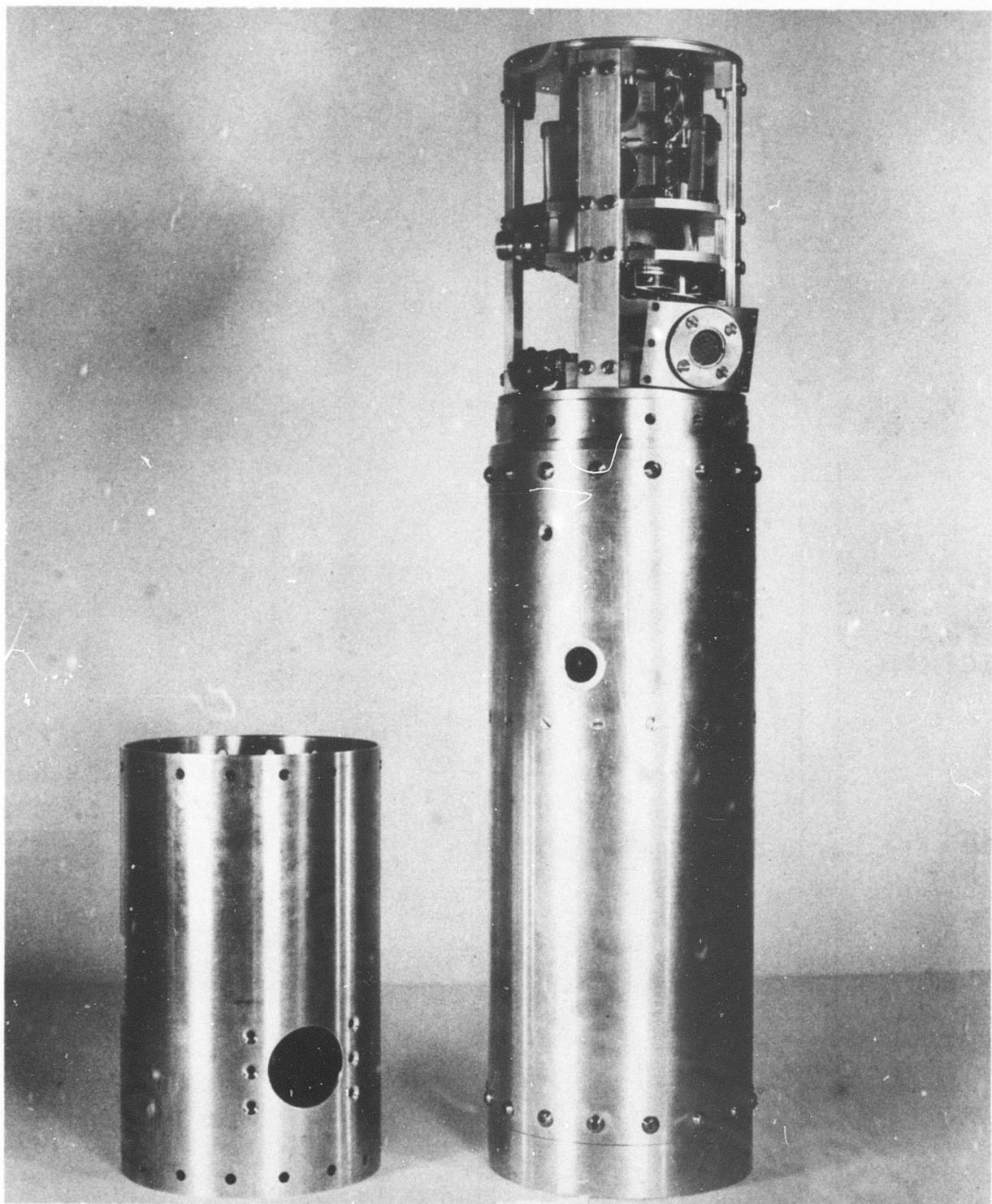


Figure 2. TMA canister and rack.

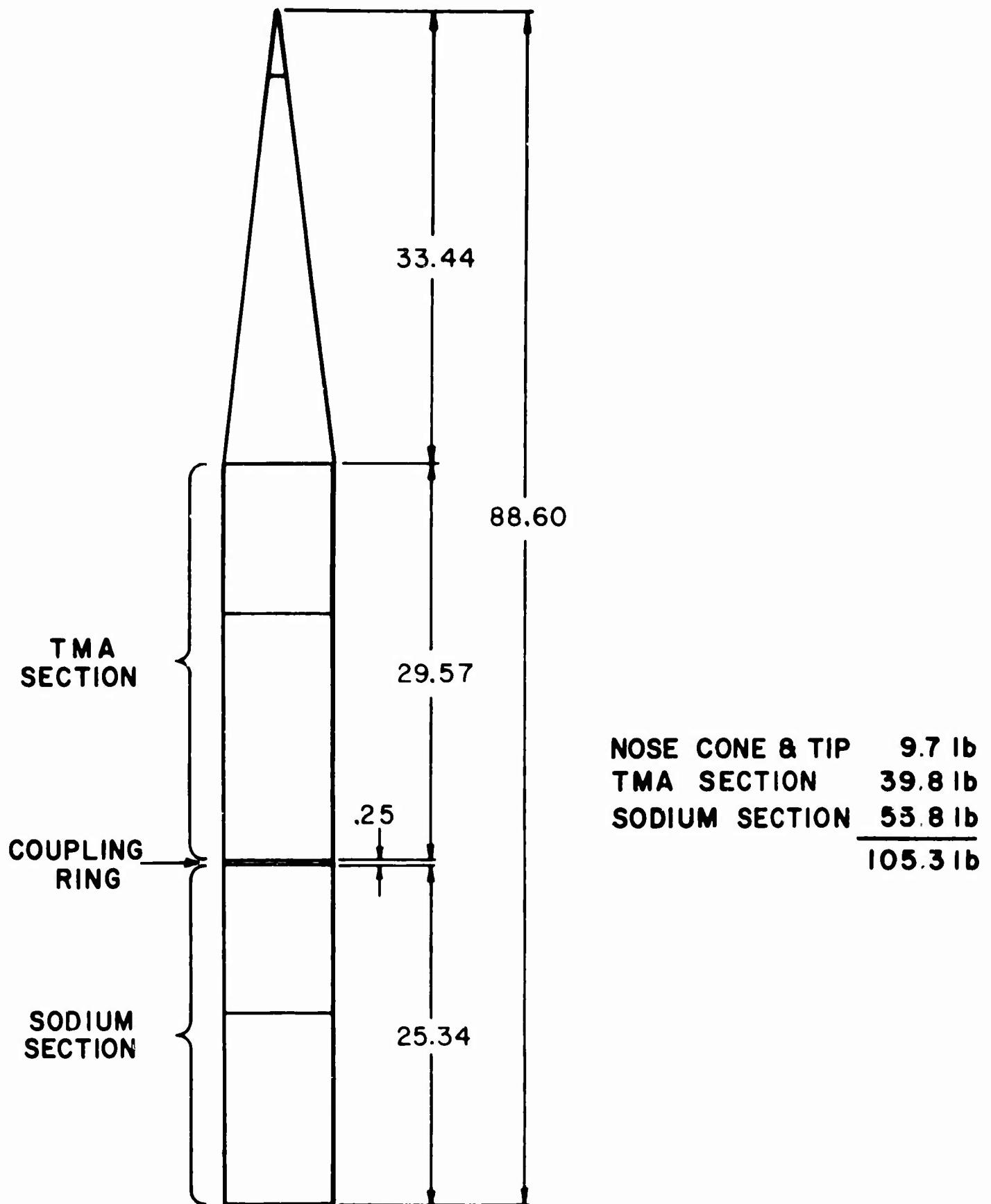


Figure 3. Combined payload configuration.

SECTION III

70-MM NIGHT CAMERAS

The design of the 70-MM night camera under Item 5 was submitted to ESD and approval of the design was received by GCA on 5 October 1965.

The determination of the specifications of this camera was based on the consideration of meeting the requirements of Items 5 and 6 with the same unit. The fabrication has been completed. The units are interchangeable and suitable for both twilight and nighttime applications with the proper film, filter, and exposure time. The lens selected for the cameras is the Summarex, f/1.5, 85-MM focal length. Each lens was bench tested prior to purchase. The distortion over a 30 degree field of view is negligible (see Data Reduction Techniques). A front view of the cameras is shown in Figure 4 and a rear view in Figure 5.

The cameras were fine focussed with photographs of stars used as standards, and the operation of the timing and fiducial lights, the shutter solenoid, and magazine transport were tested and adjusted with the use of live film.

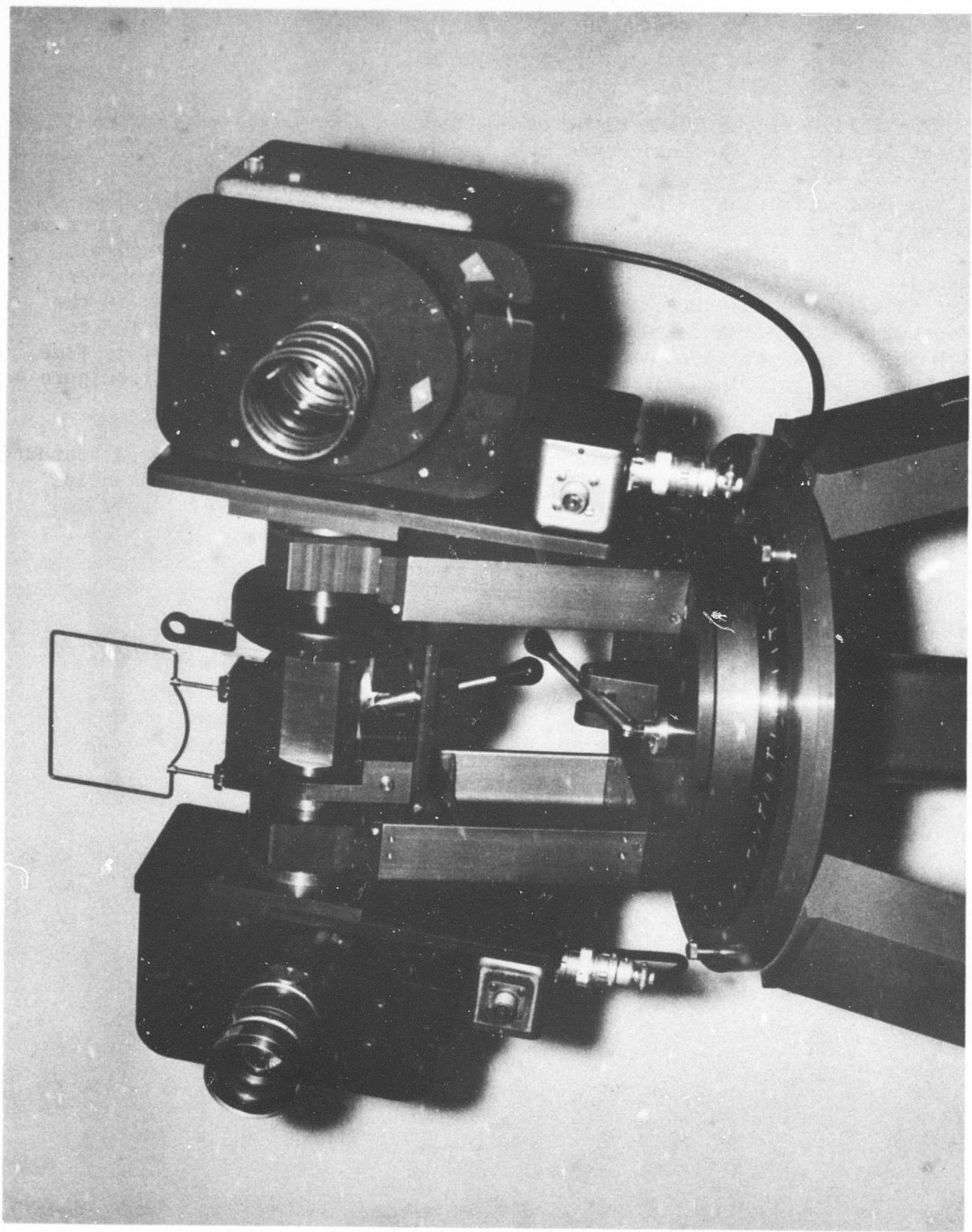


Figure 4. 70-MM night cameras (front view).

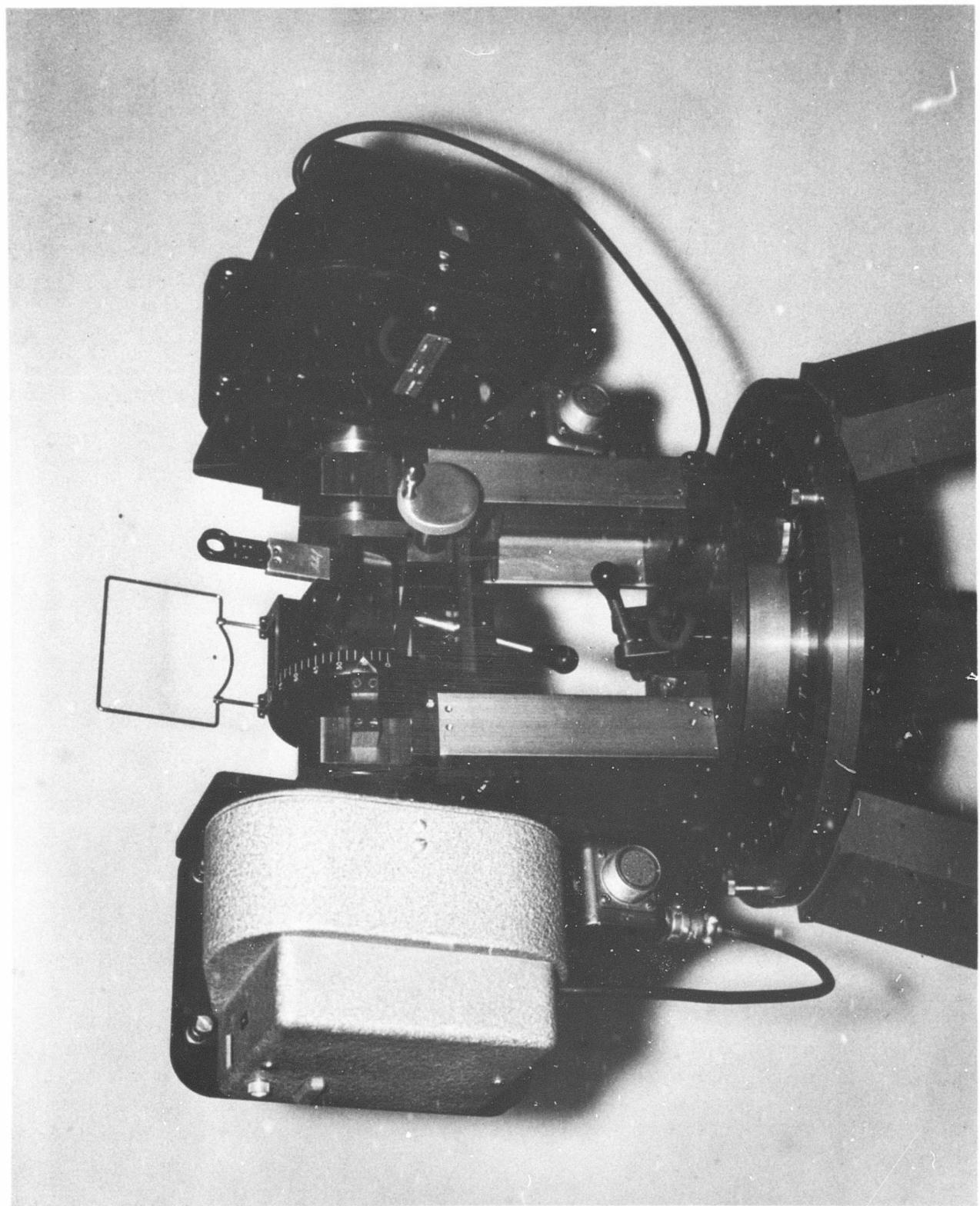


Figure 5. 70-M night cameras (rear view).

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SECTION IV

CAMERA CONTROL CONSOLE

The design of the control console under Item 6 was submitted to ESD and approval of the design was received by GCA. The fabrication of the unit is complete. The front panel and chassis is shown in Figure 6.

This console supplies and regulates the magazine power, shutter solenoid, lens heaters, fiducial and timing lights, and contains two separate programming circuits and provision for synchronization with absolute time. The two separate programming circuits provide individual framing and exposure rates for each of the two cameras on the mount. Exposure durations are adjustable between one and fifteen seconds, and the framing rates are presently set at four frames/min and at ten frames/min. It is anticipated that the slower framing rate will be used for cloud trail photography and the higher rate for trajectory data.

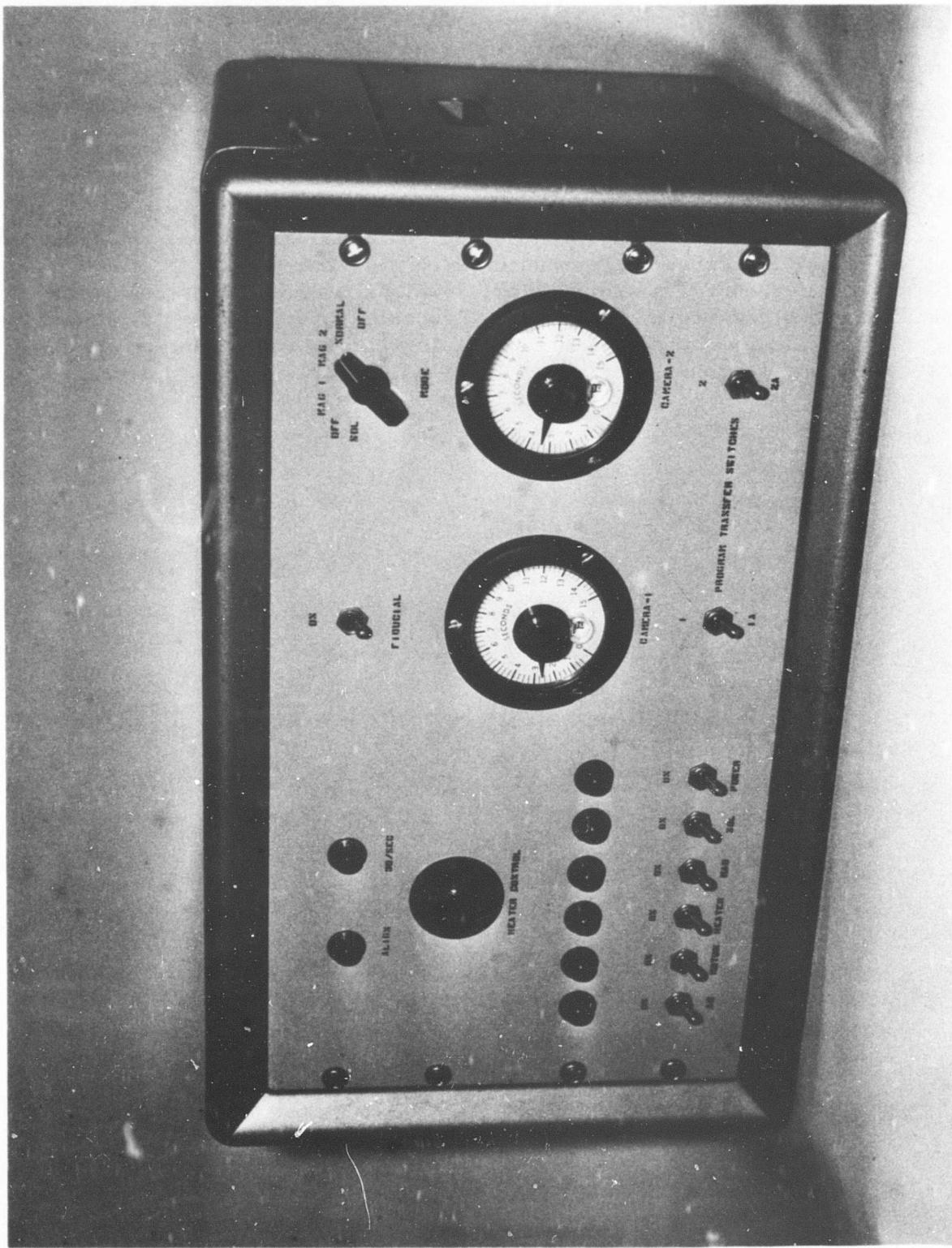


Figure 6. 70-MN camera control console.

SECTION V

CAMERA MOUNT

The design of the camera mount (Item 6) was also approved by ESD and the fabrication of the unit is complete. The mount is adjustable 360° in azimuth and 90° in the zenith plane, with positive positioning in five degree increments. The 70-MM camera, control console, and mount are shown in Figure 7.

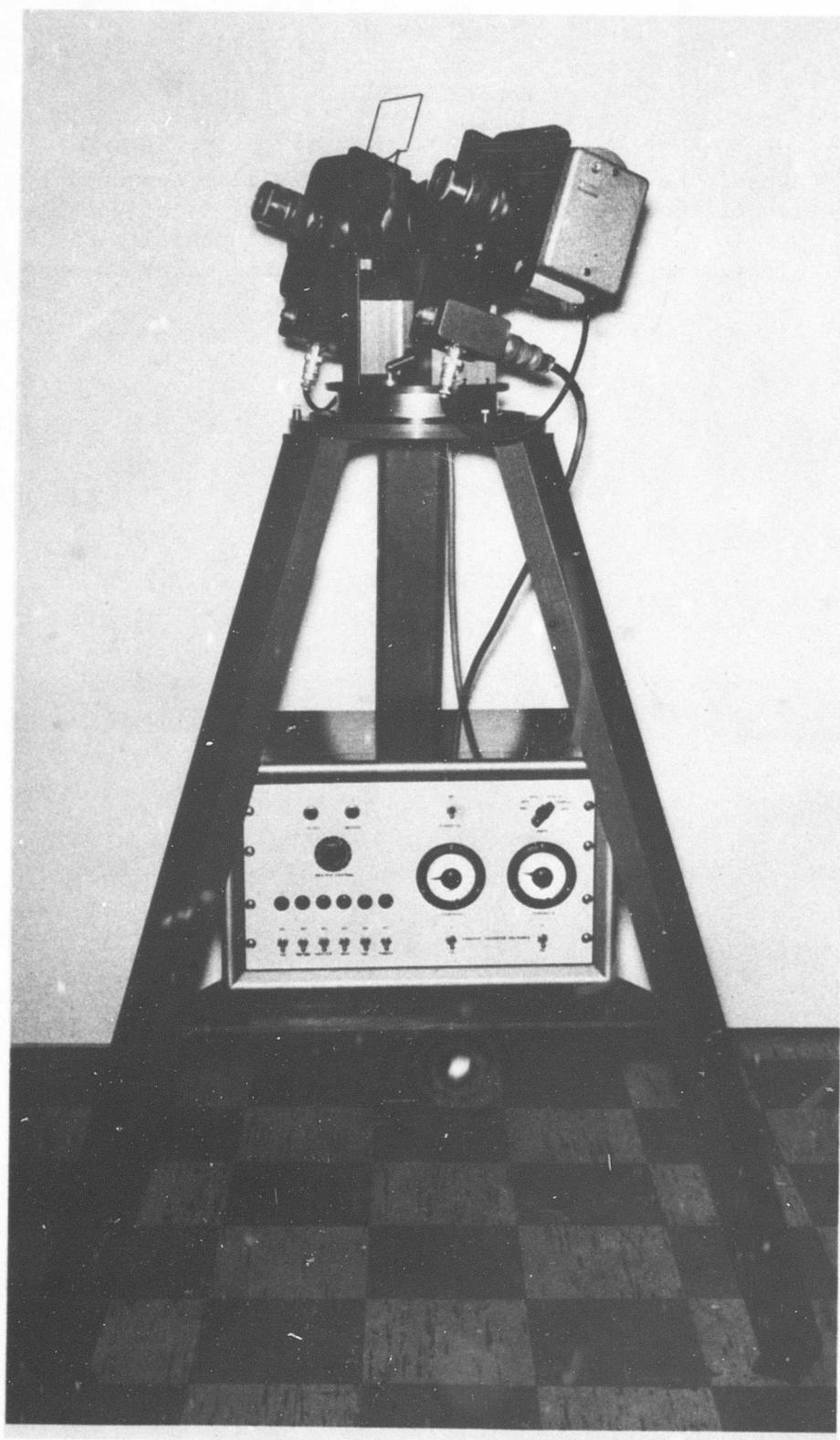


Figure 7. 70-MM cameras, console, and mount.

SECTION VI

PHOTOGRAPHIC DATA REDUCTION TECHNIQUES

In order to meet the requirement of rapid reduction of trail photographs to obtain wind velocity (Item 7), the stereo projection technique must utilize pre-computed plate constants and azimuth and elevation grids. For this technique, the scale of the plate and the linearity of the scale across the field of view must be determined. Figure 8 is a copy of a two-minute star exposure taken to determine these factors using a f/1.5, 85-MM lens on a 70-MM format.

Twenty-eight stars were identified on this plate and their azimuth and zenith angles from the camera position were computed from the following expressions:

$$\cos Z = \sin \phi \sin \delta + \cos \phi \cos \delta \cos H \quad (1)$$

$$\cos A = \frac{\sin \delta - \sin \phi \cos Z}{\cos \phi \sin Z} \quad (2)$$

$$\sin A = \frac{\cos \delta \sin (24-H)}{\sin Z} \quad (3)$$

$$H = \theta - \alpha \quad (4)$$

where Z = zenith angle

A = azimuth angle

α = right ascension

δ = declination

ϕ = latitude of camera position

H = hour angle

θ = local sidereal time

From these data the scale of the plate was determined to be 1 mm/40 min of arc and concentric circles of radii 5, 10, 15, and 20 degrees were scribed about the plate center. The plate was then projected at a magnification of 6.6 (Figure 8 is an 3.5 enlargement) onto a linear grid with the origin at the center of the plate. Cartesian coordinates were read for the 28 stars and several sets of plate constants were computed according to the following Program.

Five sets of plate constants were computed, one using only stars within a 5 degree radius of the plate center, a second with stars from the 5 to 10

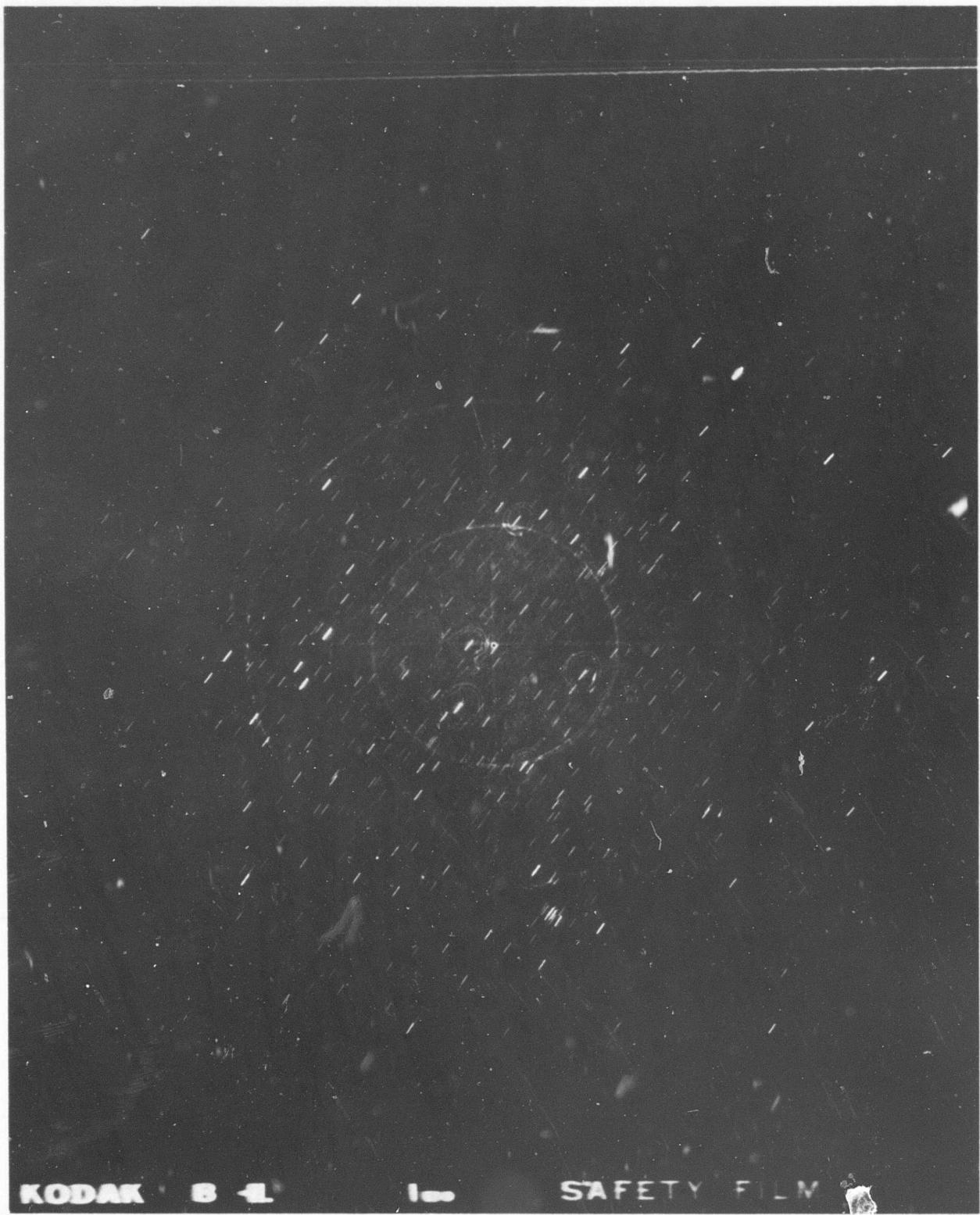


Figure 8. Two-minute star exposure.

degree zone, a third from the 10 to 15 degree zone, a fourth from the 15 to 20 degree zone, and a composite fifth set with stars selected from the previous four zones. Then using the 28 stars as test points of known azimuth and zenith angle (computed using Equations (1) through (4)) their azimuth and zenith angles were again computed using the five different sets of plate constants.

The results show that the difference between the actual angles and the angles computed with plate constants from all except the 15 to 20 degree zone are less than 2 or 3 minutes of arc. Differences of this order are inherent in the projection technique and are not attributed to appreciable distortion in the lens. However, beyond 15 degrees from the center of the plate the differences are on the order of 7 or 8 minutes of arc and lens distortion becomes appreciable.

The investigation shows that for this application the lens may be considered linear across a 30 degree circular field with a plate scale of 1 mm/40 min of arc. A linear azimuth and elevation grid may be constructed and trail points read to an accuracy of approximately 3 min of arc.

The computer program for the above calculations follows:

```

DIMENSION RA(10),DE(10),FTA(10),ZETA(10),X(10),Y(10),AR(3,3)
DIMENSION AX(3),BX(3),AV(3,2),V(3,2)
C      READ THE APPROXIMATE AZIMUTH AND ELEVATION OF THE CAMERA
C      FOLLOWED BY ITS LATITUDE AND THE LOCAL SIDEREAL TIME
C      OF THE STAR EXPOSURE
C
C      791 DO 2 I=1,4
      READ 1,XL,XM,Z
      2 RA(I)=(XL+XM/60.0+Z/3600.0)*3.14159265
      AC=RA(1)/12.0
      EC=RA(2)/180.0
      PHI=RA(3)/180.0
      THFTA=RA(4)/12.0
C
C      FIND APPROXIMATE R.A. AND DEC. OF THE CAMERA
C
      Z=SIN(PHI)*SIN(EC)+COS(PHI)*COS(EC)*COS(AC)
      DEC=ATAN(Z/SQRT(1.-Z*Z))
      Z=(SIN(EC)-SIN(PHI)*SIN(DEC))/(COS(PHI)*COS(DEC))
      HC=ATAN(SQRT(1.-Z*Z)/Z)
      IF (Z) 91,92,92
      91 HC=HC+3.14159265
      92 IF(SIN(AC)) 3,4,4
      3 HC=-HC
      4 RAC=THETA-HC
C
C      READ R.A. AND DEC. OF EACH STAR AND
C      CALCULATE THE STANDARD COORDINATES
C
      READ 6,N
      DO 5 I=1,N
      READ 1,XL,XM,Z
      RA(I)=(XL+XM/60.0+Z/3600.0)*3.14159265/12.0
      READ 1,XL,XM,Z
      DE(I)=(XL+XM/60.0+Z/3600.0)*3.14159265/180.0
      Q=ATAN(SIN(DE(I))/(COS(DE(I))*COS(RA(I)-RAC)))
      FTA(I)=SIN(Q-DEC)/COS(Q-DEC)
      5 ZFTA(I)=COS(Q)*SIN(RA(I)-RAC)/(COS(RA(I)-RAC)*COS(Q-DEC))
C      READ THE COORDINATES OF THE STARS FROM THE STAR PLATE
C
      901 CONTINUE
      DO 43 I=1,N
      43 READ 42, X(I),Y(I)
C
C      SET ALL ACCUMULATORS TO ZERO
C
      DO 7 I=1,3
      DO 116 J=1,2
      116 V(I,J)=0.0
      DO 8 J=1,3
      8 AR(I,J)=0.0
      7 CONTINUE
C
C      PREPARE THE MATRIX AND VECTORS USED TO CALCULATE THE PLATE
C      CONSTANTS
C
      DO 9 I=1,N
      AR(1,1)=AR(1,1)+X(I)*X(I)
      AR(2,2)=AR(2,2)+Y(I)*Y(I)
      AR(3,1)=AR(3,1)+X(I)

```

```

AR(3,2)=AR(3,2)+Y(I) 56
AR(2,1)=AR(2,1)+X(I)*Y(I) 57
V(1,1)=V(1,1)+X(I)*ZETA(I) 38
V(1,2)=V(1,2)+X(I)*ETA(I) 39
V(2,1)=V(2,1)+Y(I)*ZETA(I) 40
V(2,2)=V(2,2)+Y(I)*ETA(I) 41
V(3,1)=V(3,1)+ZETA(I) 42
9 V(3,2)=V(3,2)+ETA(I) 43
AR(3,3)=N 44
AR(1,2)=AR(2,1) 45
AR(2,3)=AR(3,2) 46
AR(1,3)=AR(3,1) 47
BIGM=AR(1,1)*(AR(2,2)*AR(3,3)-AR(2,3)*AR(3,2)) 47
BIGM=BIGM-AR(1,2)*(AR(2,1)*AR(3,3)-AR(2,3)*AR(3,1)) 472
BIGM=BIGM+AR(1,3)*(AR(2,1)*AR(3,2)-AR(2,2)*AR(3,1)) 473
DO 17 I=1,2 474
  AV(1,I)=V(1,I)*(AR(2,2)*AR(3,3)-AR(2,3)*AR(3,2)) 475
  AV(1,I)=AV(1,I)-V(2,I)*(AR(2,1)*AR(3,3)-AR(2,3)*AR(3,1)) 476
  AV(1,I)=AV(1,I)+V(3,I)*(AR(2,1)*AR(3,2)-AR(2,2)*AR(3,1)) 477
  AV(2,I)=AR(1,I)*(V(2,I)*AR(3,3)-V(3,I)*AR(3,2)) 478
  AV(2,I)=AV(2,I)-AR(1,2)*(V(1,I)*AR(3,3)-V(3,I)*AR(3,1)) 479
  AV(2,I)=AV(2,I)+AR(1,3)*(V(1,I)*AR(3,2)-V(2,I)*AR(3,1)) 480
  AV(3,I)=AR(1,I)*(AR(2,2)*V(3,I)-AR(2,3)*V(2,I)) 481
  AV(3,I)=AV(3,I)-AR(1,2)*(AR(2,1)*V(3,I)-AR(2,3)*V(1,I)) 482
  AV(3,I)=AV(3,I)+AR(1,3)*(AR(2,1)*V(2,I)-AR(2,2)*V(1,I)) 483
  DO 18 K=1,3
18 AV(K,I) = AV(K,I)/BIGM
17 CON:INUF 484
C 49
C 50
C      FIND THE CONSTANTS FOR CHANGING FROM TRAIL COORDINATES 51
C          TO THE STANDARD COORDINATES OF THE STAR PLATE 52
C          AND PUNCH ON CARDS WITH DEC. AND R.A. 53
C 54
      A = AV(1, 1)
      B = AV(2, 1)
      C = AV(3, 1)
      D = AV(1, 2)
      E = AV(2, 2)
      F = AV(3, 2)
      PRINT 81, A, B, C, D, E, F
81 FORMAT (12H A B C D E F //6F12.6//21H TEST ON ZETA AND ETA//)
      DO 10 I = 1, N
        TZ = A*X(I) + B*Y(I) + C
        TE = D*X(I)+E*Y(I) + F
        PRINT 93, ZETA(I), TZ, ETA(I), TE
93 FORMAT(4F15.6)
10 CONTINUF
      PUNCH 42,DEC,RAC
      PUNCH 42,A,B,C,D,F,F
      GO TO 791
42 FORMAT(F13.6,F13.6)
1 FORMAT(F3.0,F3.0,F6.2)
6 FORMAT (I3)
      END 56

```

```

C      READ IN THE DATA FROM PROG.1B WITH THE LATITUDE AND LOCAL
C          SIDEREAL TIME OF A POINT BELOW THE TRAIL
C
 99 READ 42, DEC, RAC
    READ 42, A, B, C, D, E, F
 42 FORMAT(F13.6, F13.6)
    READ 1, L, M, Z
    XL=L
    XM=M
    PHI=(XL+XM/60.0+Z/3600.0)*3.14159265/180.0
    READ 1, L, M, Z
    XL=L
    XM=M
    THETA=(XL+XM/60.0+Z/3600.0)*3.14159265/12.0
 1 FORMAT(I3, I3, F6.2)          12      16
C
C      READ THE COORDINATES OF EACH TRAIL POINT AND FIND IN ORDER
C          THE STANDARD COORDINATES, THE R.A. AND DEC., AND THE
C          AZIMUTH AND ELEVATION AND PUNCH THE LAST TWO ON CARDS
C
 23 READ 42, XX, YY
    IF (IXX - 1.0E5) 98, 99, 99
 98 XI=A*XX+B*YY+C
    XN=D*XX+F*YY +F
    RA=RAC+ATAN(XI/(COS(DEC)*(1.-XN*SIN(DEC)/COS(DEC))))
    DF=ATAN(SIN(RA-RAC)*(XN+SIN(DEC)/COS(DEC))*COS(DEC)/XI)
    H=THETA-RA
    Z=SIN(PHI)*SIN(DE)+COS(PHI)*COS(DE)*COS(H)
    FL=ATAN(Z/SQRT(1.-Z*Z))
    Z=(SIN(DE)-SIN(PHI)*SIN(EL))/(COS(PHI)*COS(EL))
    AZ=ATAN(SQRT(1.-Z*Z)/Z)
    IF(Z) 94, 95, 95
 94 AZ=AZ+3.14159265
 95 Z=SIN(H)
    IF(Z) 96, 97, 97
 96 AZ=0.0-AZ
 97 PUNCH 42, FL, AZ
    GO TO 23
    END

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13. ABSTRACT

Payloads consisting of TMA and sodium were constructed and one was flown from the Eglin Test Range in Florida. Two 70-MM cameras suitable for twilight and night trail photography were designed and developed along with an adjustable camera mount for pointing in azimuth and elevation and a timing console for sequentive automatic exposures. Refinements of existing procedures for obtaining estimated wind velocity data led to the development of photographic projection techniques, which can be programmed for use with a computer.

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